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VARIABLE SHIP SPEED AND USABLE LIFE TESTS OF NYLON-COATED, SURF--ETC(U)
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final report: **Variable Ship Speed and Usable Life Tests of Nylon-Coated, Surface-Vessel, Bathythermograph Hoisting Cable**

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STATEMENT OF PROBLEM

BuShips problem NEL 4G1: Test nylon-coated, surface-vessel, bathythermograph hoisting cable considered for use in sonar work. This final report covers the conclusion of the variable ship speed tests and the usable life tests of the cable (recommended in NEL Report 177), and correlates the entire testing program.

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CONCLUSIONS

1. The effective usable life of the nylon-coated cables is from 1000 to 1100 instrument lowerings.
2. Operating at a towing speed of from 2 to 12 knots, the nylon-coated cables permit equivalent allowable instrument depths to those obtained with standard uncoated cables of smaller outside diameter.
3. The nylon-coated cables are more resistant to corrosion than standard uncoated cables of the same type.
4. The minimum thickness of nylon coating for field applications is 1/32 in.
5. The nylon coating is highly susceptible to abrasion damage.
6. Nylon-coated cables are superior to uncoated cables from the operator's standpoint.

RECOMMENDATIONS

1. Nylon-coated cables (minimum thickness of coating, 1/32 in.) should be used in applications where cables are required to operate under abnormal corrosive conditions.
2. Investigate sheave materials for nylon-coated cables, in order to find a way to lower abrasive damage to the coating surface.
3. Investigate the possibility of a cable coating with a higher degree of abrasion resistance.

WORK SUMMARY

Over 2500 test lowerings were made with standard and dummy-standard deck-type bathythermographs. Accelerated life tests and tests at different ship towing speeds were made with the cable.

The majority of the sea tests were performed by marine technicians of the Scripps Institution of Oceanography under the supervision of Robert Sampson, John Cochrane, of the SIO Bathythermograph Section, furnished many valuable data.

This report covers work to 1 June 1951.

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INTRODUCTION

The Bureau of Ships requested the Navy Electronics Laboratory to test four different sizes of nylon-coated, surface-vessel bathythermograph hoisting cable, manufactured by the Danielson Manufacturing Company, Danielson, Connecticut (trade name, Danco Cables). Preliminary tests conducted by the Woods Hole Oceanographic Institution had indicated that the nylon coating appeared to render the cable very nearly kink-proof, to increase the life of the cable, and to make the cable safer to handle.

As an interim report on this problem, NEL Report 177 covered the extent of the evaluation to April 1950 of this hoisting cable under service conditions at sea, stressing effect of coating thickness, performance at different ship speeds, durability of the coating, anti-corrosion characteristics, cable life, kinking characteristics, and advantages and disadvantages from the operator's viewpoint.+ The present report covers the final testing program, which included tests of the cable at additional and more varied ship speeds, the conclusion of the accelerated life tests, and a correlation of the entire testing program. The four different sizes of cables under test in this problem are listed below:

Cable 1	1/16 in. wire diameter	1/64 in. coating
2	1/16 in. wire diameter	1/32 in. coating
3	3/32 in. wire diameter	1/64 in. coating
4	3/32 in. wire diameter	1/32 in. coating

These cables were subjected to a total of 2650 bathythermograph lowerings during all phases of the test program, 1275 lowerings since the interim report. Only cables 2 and 3 were used in the final testing program. Cable 4 had been lost over the side after 407 lowerings; cable 1 was not strong enough to permit normal bathythermograph lowerings with safety.

TESTING PROGRAM

Test lowerings on cables 2 and 3, made from 1 January 1950 to 15 August 1950, were carried out as part of the oceanographic and hydrographic operations of the Scripps Institution of Oceanography, using the ships MV CREST, MV HORIZON, and E. W. SCRIPPS. The lowerings were made from standard deck bathythermograph winches, except for 334 lowerings on cable 3, which were made with a new type hoist, the Submarine Signal Corporation Type E-2/S, Pre-production Model X2.

+Stark, L. B., Evaluation of Nylon-Coated, Surface-Vessel, Bathythermograph Hoisting Cable, NEL Report 177, 26 May 1950.

The basic test program schedule called for towing at ship speeds of 2, 4, 6, 8, 10, and 12 knots, making as many runs as possible within the operating schedules of the three ships available. The usable life tests, making bathythermograph lowerings as rapidly as practicable, were continued until the cable under test would no longer perform effectively under standard bathythermograph lowering procedures.

As a vital part of the analysis of coating failures, macrophotographs were taken of the cable by means of special accessory equipment designed and developed at the Laboratory. This accessory equipment was used in a standard Bausch and Lomb Industrial Type Metallograph with proper optics and adaptation for low-power magnification (6 to 10 times) of the failing sections of cable coating.

RESULTS

VARIABLE SHIP SPEED TESTS

The data summarized in tables 1 and 2 give the amount of cable required to reach a given depth for different ship speeds. The average ratios indicated may be readily interpreted by a short rule: A ratio of 1.0 would mean 1 foot of instrument depth for every foot of cable reeled out, and a ratio of 2.0 would mean 1 foot of instrument depth for every 2 feet of cable reeled out. For Cable 2, it is evident that the amount of cable required to reach a given depth more than doubles as the ship speed increases from 2 to 12 knots. The average ratio for a towing speed of 2 knots on Cable 2 with 400 feet of cable out is 1.11; while at 12 knots with 950 feet of cable out, the ratio is 2.31. In both cases, the instrument depths reached were approximately 400 to 430 feet.

The data for Cable 3 show the same trend for the amount of cable required to reach a given depth of instrument for different ship speeds, understandable since the outside diameters of both cables are exactly the same. In addition, the actual ratios at the lowest and highest ship speeds are practically identical for Cables 2 and 3. In the case of Cable 3, the average ratio for a towing speed of 2 knots is 1.09 for 400 feet of cable out and a towing speed of 12 knots, and 2.30 with 950 feet of cable out (as compared with average ratios of 1.11 and 2.31, respectively, for Cable 2).

It is possible to compare the allowable instrument depths of 1/8 in. OD nylon-coated cable, such as Cables 2 and 3, with standard, 3/32 in. OD uncoated bathythermograph cable (see pp. 7 and 8 of Table 3, and Figure 22 on p. 26, of NEL Report 177). The average ratio is 1.11 for 0 knots and 450 feet of standard cable out, and 2.33 for 10 knots and 850 feet of standard cable out.

Table 1. Ratio of Cable Length Lowered to Instrument Depth Reached: Cable 2 (1/8 in. OD, 1/32-in. coating)

Speed (knots)	Total Cable Out (feet)	Maximum Ratio	Minimum Ratio	Average Ratio
2.0	400	1.18	1.03	1.11
2.0	500	1.22	1.14	1.17
4.45	400	1.31	1.19	1.25
4.0	500	1.28	1.27	1.28
4.35	500	1.27	1.06	1.17
6.0	400	1.57	1.31	1.47
6.0	600	1.62	1.45	1.53
6.0	800	1.63	1.52	1.58
8.0	400	1.91	1.60	1.75
8.0	600	1.85	1.67	1.75
8.0	800	1.88	1.65	1.78
10.0	900	2.25	2.00	2.08
12.0	950	2.50	2.11	2.31

The data for standard, 3/32-in. OD uncoated bathythermograph cables conclusively show that the same instrument depths can be reached with the 1/8 in. OD nylon-coated cables, despite an over-all diameter increase of 25 per cent. This favorable comparison indicates a lower drag in the water for nylon-coated cables used under bathythermograph lowering conditions, in the towing speed range from 0 to 12 knots. This characteristic of the nylon-coated cables is certainly advantageous from a standpoint of bathythermograph lowering operations, since it results in lower drag loads on cables in service, and provides higher efficiencies of instrument depths allowable for total cable lengths in use.+

Table 2. Ratio of Cable Length Lowered to Instrument Depth Reached: Cable 3 (1/8 in. OD, 1/64 in. coating)

Speed (knots)	Total Cable Out (feet)	Maximum Ratio	Minimum Ratio	Average Ratio
2.0	400	1.14	1.04	1.09
2.0	600	1.46	1.36	1.42
4.0	500	1.28	1.21	1.24
6.0	400	2.11	1.54	1.75
6.0	600	1.97	1.52	1.70
6.0	800	1.68	1.55	1.62
6.3	400	2.11	1.51	1.73
8.0	400	1.74	1.46	1.63
8.0	600	2.22	1.71	1.85
8.0	800	1.95	1.70	1.81
10.0	900	2.25	2.00	2.11
10.0	950	2.21	2.11	2.16
12.0	950	2.22	2.22	2.30

+A nylon-coated cable of 3/32 in. OD would reach greater instrument depth at a decrease in cable length, as compared to a standard uncoated 3/32 in. OD cable.

USABLE LIFE TESTS: CABLE COATING FAILURES

Tables 3 and 4 summarize the types of damage to Cables 2 and 3 as the number of lowerings increased. In the final phase of the cable usable life tests and towing tests at different speeds a large number of cable-coating failures occurred in both of the cables under test. After removal from service following 1018 lowerings, Cable 2, with a 1/32-in. nylon coating showed a total of 23 serious coating failures in a 196-foot section starting at the bathythermograph end. In marked comparison to these coating failure conditions, after a total of 1064 lowerings and removal from service, Cable 3, with a 1/64-in. nylon coating, showed a total of 87 serious coating failures in a 300-foot section starting at the bathythermograph end. In addition to these 87 coating failures in this portion of Cable 3, a total of 28 previous severe coating failures had occurred in sections previously cut from the bathythermograph end of Cable 3.

These results show that Cable 2, with the 1/32-in. nylon coating, suffered a total of only 23 serious coating failures as compared with the total of 115 serious coating failures for Cable 3, with the 1/64-in. nylon coating. This finding is quite significant, since it shows that after the same service life test conditions involving over 1000 lowerings for each cable, the thinner wall nylon coating showed five times the number of serious coating failures, these failures extending over 150 feet more than the coating failures in the cable with the thicker coating.

The detailed cable failures are illustrated in figures 1 through 22. Figure 1 is a typical example of a severe tear in the 1/64-in. thick coating of Cable 3. Extreme fraying and distortion is evident at the torn coating edges. The coating failure shown in figure 2 shows the effect of severe abrasion in a section of Cable 3 within 20 feet of the bathythermograph end of the cable. The abrasion caused a longitudinal tear in the 1/64-in. nylon coating as well as secondary spiral cuts and peeling along the edges of the tear.

It is important to note the type of coating failure in figure 3, since this type of coating separation occurred in both cables. In this failure the nylon coating split and then pulled completely away from the wire core. This particular peeled area was in Cable 3, approximately 10 feet from the bathythermograph end. The 20-foot section closest to the end of the cable and containing this failure was severed from the cable after 764 lowerings. Figures 4 and 5 are illustrative of severe abrasion most likely due to edge rubbing on the sheave. These damage areas were both in the same 20-foot section of Cable 3 that contained the

Table 3. Cable Damage vs Number of Lowerings - Cable 2 (1/8 in. OD, 1/32 in. coating)

Lowerings	Speed (knots)	Extent of Damage
1-452	2-8	Cable BT end was trimmed to remove any prior damage.
453-608	8 and 10	Slight kink near BT end and minor surface abrasions intermittently on 20 feet nearest BT end.
609-711	6 and 10	The last 2 feet of nylon coating next to BT stripped off. Apparently caused by kink leading to fouling in a jig line and sheave abrasion. Last 2 feet were cut off.
712-737	10	Several minor surface cuts on the coating throughout the last 15 feet near the BT end. None of these cuts extended to the wire core. One severe cut and initial peeling of the nylon coating at 10 feet from the BT end. This latter area is where the cable contacts the guide sheave for a definite period of time while the BT is equalizing to the water temperature.
738-766	10 and 12	Nylon coating badly frayed for the last two feet of cable next to the BT end. Surface abrasions and cuts intermittently on the last 20 feet next to the BT.
767-744	10 and 12	Nylon coating badly frayed and starting to peel off of wire core over a 20 foot length next to the winch, approximately 900 feet from the BT.
775-1018	2,4,6, 7.5,8, 10 and 12	Severe coating failures, intermittent abrasions, cuts, peeling in the last 40 feet of the coating next to the BT. Coating failures were so serious and extensive that the cable was no longer usable for BT lowerings. This was considered the practical usable life for Cable 2. Intermittent failures extended through 196 feet of the cable from the BT end.

Table 4. Cable Damage vs Number of Lowerings -
Cable 3 (1/8 in. OD, 1/64-in. coating)

Lowerings	Speed (knots)	Extent of Damage
1-355	2-8	Cable BT end was trimmed to remove any prior damage. There were several very small surface cuts in the first 40 feet of cable near the BT end, but none were serious.
356-409	8,10 and 12	Nylon coating started to peel from wire core in 5-foot section of the cable at the winch drum end.
410-430	10 and 11	Kink in cable near BT end. Cable was left intact; kink was not serious enough to cut cable.
431-622	4,8,10 and 11	Nylon coating peeling intermittently from wire core over 10- foot length next to BT end. Continued to use cable in this condition.
623-723	5,9,10 and 12	Nylon coating severely peeled and abraded over 20-foot length next to BT end. This 20-foot damaged section was cut from the cable and the BT linked to the remaining relatively undamaged cable.
724-789	5,10,11 and 12	Nylon coating peeled from wire core intermittently over 20-foot length next to BT end. This peeling was so severe the cable would not run through the sheave. This 20-foot section was cut from the cable and the BT linked to the remaining relatively undamaged cable.
790-1064	2,4,6,8, 10 and 12	Severe peeling of nylon coating in the last 30 feet of cable next to the BT end. Abrasions and cuts in the coating in this length of the cable. Coating failures were so severe that the cable was no longer usable for BT lowerings. This was considered the practical usable life for Cable 3. Intermittent failures extended through 300 feet of the cable from the BT end.

failure shown in figure 3. These photographs clearly show the varied damage which led to the removal of the defective portion of the cable, after which 300 more lowerings were made with the remainder prior to the determination that it was no longer usable.

The cable section that appears in figure 6 shows the coating failure resulting at the point where the cable is attached to the bathythermograph shackle. Localized cuts and peeling of the 1/64-in. coating of Cable 3 are typical of the failures caused by this type of cable juncture. The severe longitudinal distortion leading to a transverse "pile-up" of the 1/64-in. nylon coating is shown in different stages of severity in figures 7 and 8. This type of failure occurred at numerous points where small kinks were found in Cable 3. It is quite noticeable that knife-like transverse cracks resulted in the coating, penetrating to the wire core and creating areas where localized corrosive attack would be accelerated.

The severely torn and frayed coating section shown in figure 9 is indicative of failure conditions consisting primarily of abrasion (most probably on the sheave sides) and torsion. The spiral tears appearing in the center of the photograph are characteristic of this condition. The failure sections illustrated by figures 10 and 11 are quite distinct from the previous failures shown. These failures occurred in the 1/64-in. nylon coating of Cable 3 and are solely transverse cracks, a large number of them being of sufficient severity to cut down to the wire core. The primary cause of this type of failure is a severe kink. This indicates that kinking of the severity shown is very damaging to such thin nylon coatings and leads to cracks which would cause subsequent peeling and splitting off of the coating from the wire core.

Figures 12 and 13 show the initial stage and final result of a coating failure that resulted in full separation of the coating from the wire core. The area shown was approximately 175 feet from the bathythermograph end of Cable 3. The longitudinal split of figure 12 turns into a continuous break and leads to the complete pull-away of the nylon coating and the full exposure of the wire core, as shown in figure 13. A considerable section of the wire core is exposed, making it more susceptible to corrosive attack than other sections of the wire core.

Starting with figure 14, a group of coating failures of the types encountered in the 1/32-in. nylon coating of Cable 2 shows the marked difference between the failures that occur in the 1/32-in. nylon coating as compared to the 1/64-in. nylon coating of Cable 3. The failures shown in

figures 14, 15, and 16 are examples of the progressive stages of coating failure leading to the peeling of the 1/32-in. nylon coating from the wire core. Figure 14 illustrates an early stage of failure, where a longitudinal tear in the coating has occurred and one edge of the torn coating has started to peel from the wire core. Figures 15 and 16 show the intermediate peeling of the torn coating and, finally, the complete peeling of the coating from the wire core. This leads to a full discontinuity in the cable surface; the cable is damaged more severely as it passes through the guide sheave in this condition. Normally, a cable section with this surface condition must be cut out of the cable proper after a very small number of lowerings if it is desired to maintain the cable in service.

Types of coating failures restricted to a small area are shown in figures 17, 18, and 19; in most cases these failures did not lead to further damage which impaired the use of the cable. The fibrous peeling indicated in figure 17 appears to have been caused by localized abrasion and, in practically all cases, the fibrous peeling tore away from the remainder of the coating without further serious coating damage. Figure 18 shows a small, sharp transverse cut of a type which did not usually cause the coating to peel. Figure 19 is representative of a localized tear, most examples of which did not extend over 3/8 in. in length and often did not reach the wire core. All of the coating failures shown in figures 17, 18, and 19 are indicative of the generally higher durability of the 1/32-in. nylon coating as compared to the 1/64-in. coating shown in figures 1 through 13. These less severe failures occurred approximately 180 feet from the bathythermograph end of Cable 2.

Figures 20, 21, and 22 are examples of miscellaneous failures that occurred occasionally in Cable 2 from 150 to 190 feet from the bathythermograph. The small surface cut shown in figure 20 occurred frequently, indicating that the nylon coating is quite susceptible to surface nicks by any sharp object. It is nevertheless important to note that surface cuts of this type did not usually lead to progressive coating failures or peeling of the coating from the wire core. Figure 21 shows a type of surface abrasion failure of the 1/32-in. nylon coating, which generally consisted of the intermittent tearing out of chunks in the surface layer of short sections (1/2 to 1 in.) of the nylon coating. Although these abrasions do not add materially to severe coating failures, cumulatively they tended to roughen intermittently the cable coating surface over fairly large linear distances (50 to 100 feet) in the areas closer to the bathythermograph

end. The results of moderate to sharp kinks over short lineal distances on Cable 2 are well illustrated by the coating failures shown in figure 22. It is evident that some transverse "pile-up" of the nylon coating results from the severe longitudinal strains caused by the kinks. In general, these transverse points of coating distortion are not nearly as severe in the 1/32-in. nylon coating of Cable 2 (figure 22) as the similar kinking damage in the 1/64-in. nylon coating of Cable 3 (figures 10 and 11).

CONCLUSIONS

(1) The effective usable life of the Danco bathythermograph hoisting cables is limited by failures of the nylon coating to 1000 to 1100 lowerings. However, if field operations can use the shortened cable resulting from the removal of 100 to 300 feet of cable directly adjacent to the bathythermograph end, the remainder of the cable would permit approximately 100 to 200 more lowerings.

(2) The nylon-coated cables permit the operation of standard bathythermographs at the same range of instrument depths permitted by standard uncoated, 3/32-in. OD stainless-steel bathythermograph cables. This was fully confirmed by tests at different ship speeds, despite the fact that the diameter of the nylon-coated cable is increased by the coatings overlying the 3/32-in. wire cores. This result definitely indicates that the nylon-coated surface has a lower drag coefficient than the uncoated cable surface throughout the towing speed range of the investigation (0 through 12 knots).

(3) Although the coated cable is less susceptible to kinking than comparable uncoated cable with the same wire core, when kinking does occur, it often results in serious transverse compression "pile-up" of the nylon coating immediately adjacent to the kinked area.

(4) The nylon coating definitely causes a marked improvement over standard uncoated cables in corrosion resistance, for this type of cable and the particular loading and corrosive environment encountered in the tests.

(5) It is extremely important to note that the test results show a wide difference in service durability of the two coating thicknesses tested (1/32-in. and 1/64-in.). The 1/32-in. coating is the only one of the two that is practical from a service standpoint, and is considered to be the minimum usable coating thickness for bathythermograph lowering conditions.

(6) On the basis of the analysis of the entire range of coating failure conditions, regardless of coating thickness, it was determined that the nylon coating is

highly susceptible to abrasion damage which, in turn, generally leads to the peeling of the coating from the wire core.

(7) The nylon-coated cables are generally superior to uncoated cables from the standpoint of over-all operational handling. All comments from bathythermograph operating crews favored the coated cable over the uncoated cable under all operating conditions, especially where injuries could be caused by frayed or exposed wires.

RECOMMENDATIONS

(1) If nylon-coated bathythermograph cables are to be used for service applications, the minimum thickness of nylon coating utilized should be 1/32-in.

(2) Wherever extreme corrosion resistance is a highly important factor in bathythermograph lowering operations, the nylon-coated cables should be considered for use.

(3) In order to utilize to a fuller extent the desirable properties of nylon-coated bathythermograph lowering cables, an investigation of sheave materials should be authorized and carried out, in order to find methods to lower abrasive damage to the nylon coatings that occur through sheave contact factors. The feasibility of using molded, or molded and finish-machined, nylon sheaves should be determined as an integral part of such an investigation.

(4) Further investigation should also be made into the possibility of obtaining a coating with a higher degree of abrasion resistance than the coatings tested.

(5) Danco Sealer No. 4 (manufactured by the Danielson Manufacturing Company, Danielson, Connecticut), or equivalent, should be used on all cable terminations. If such a sealer had been available during this testing program, it is most probable that the fraying of the coating near cable terminations and subsequent wire-core corrosion could have been prevented.

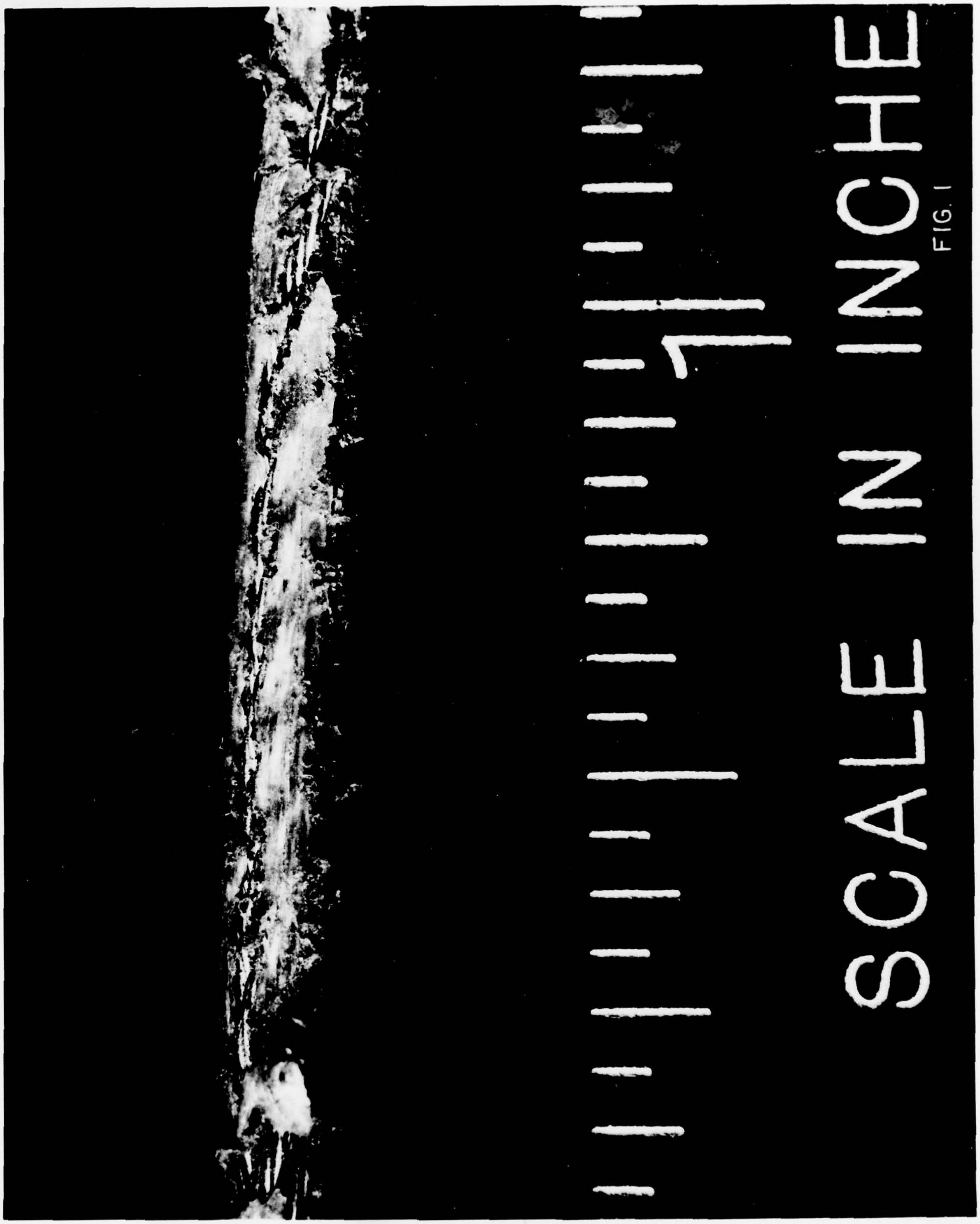

FIG. 1

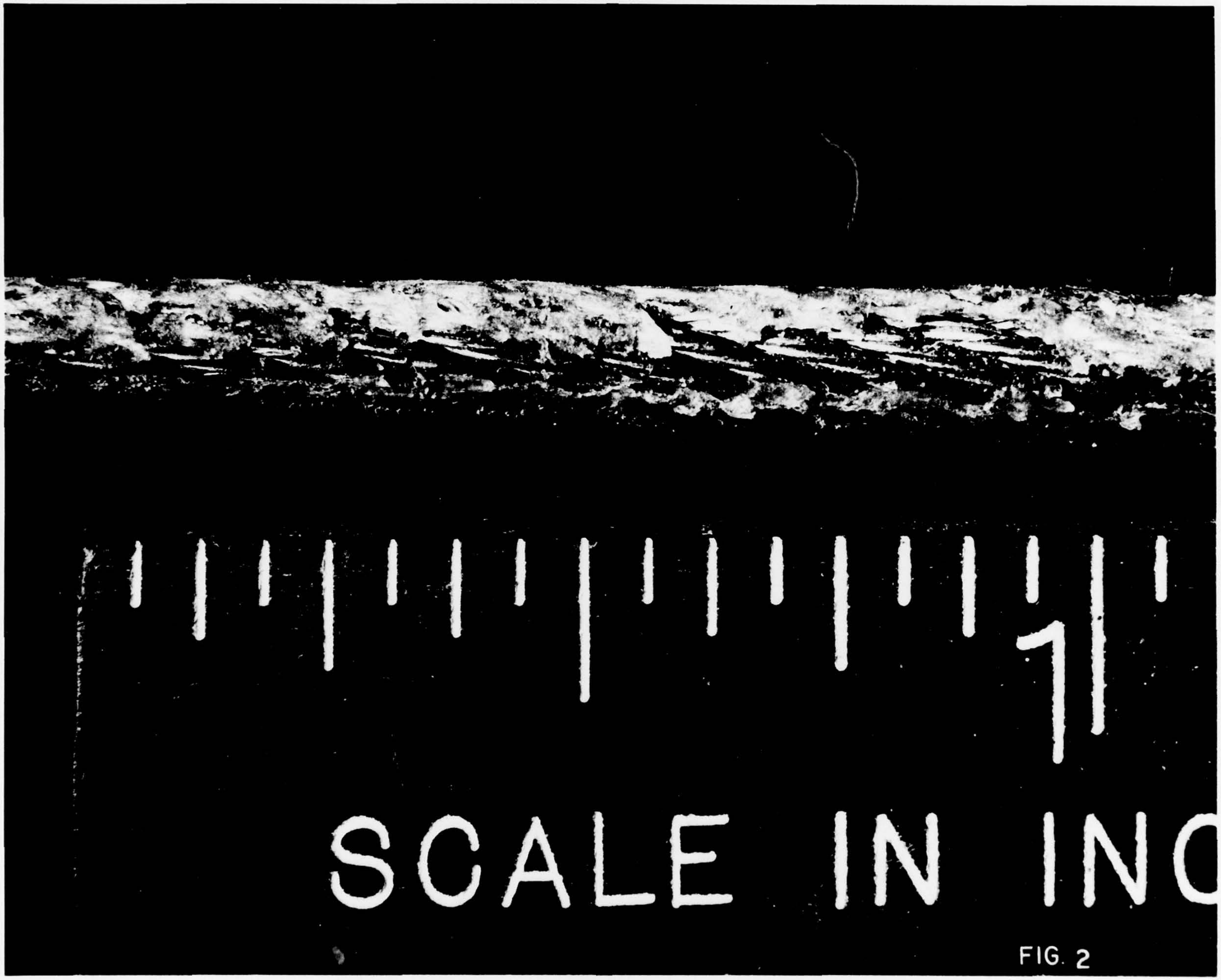

FIG. 2

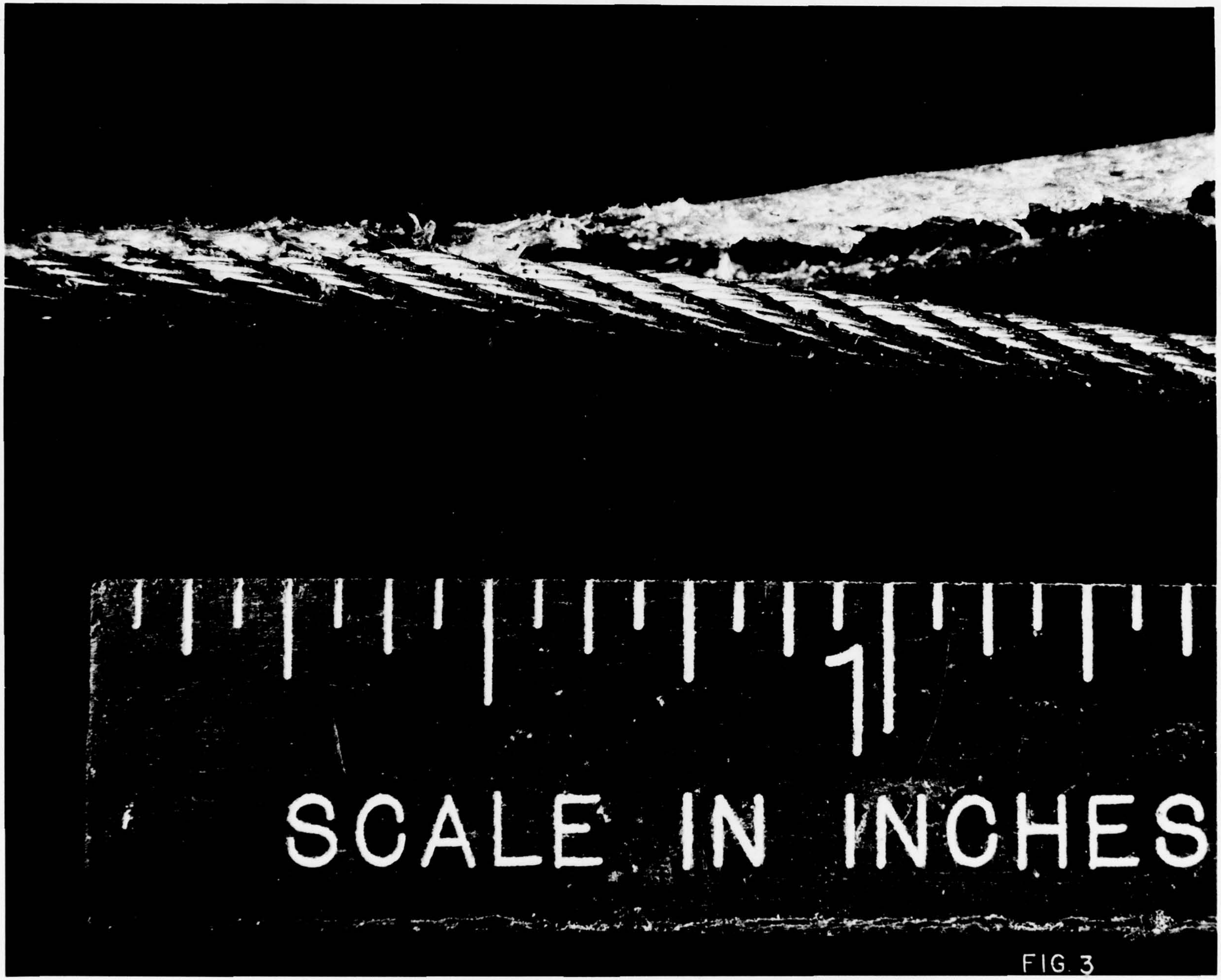
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FIG 3

FIG.4

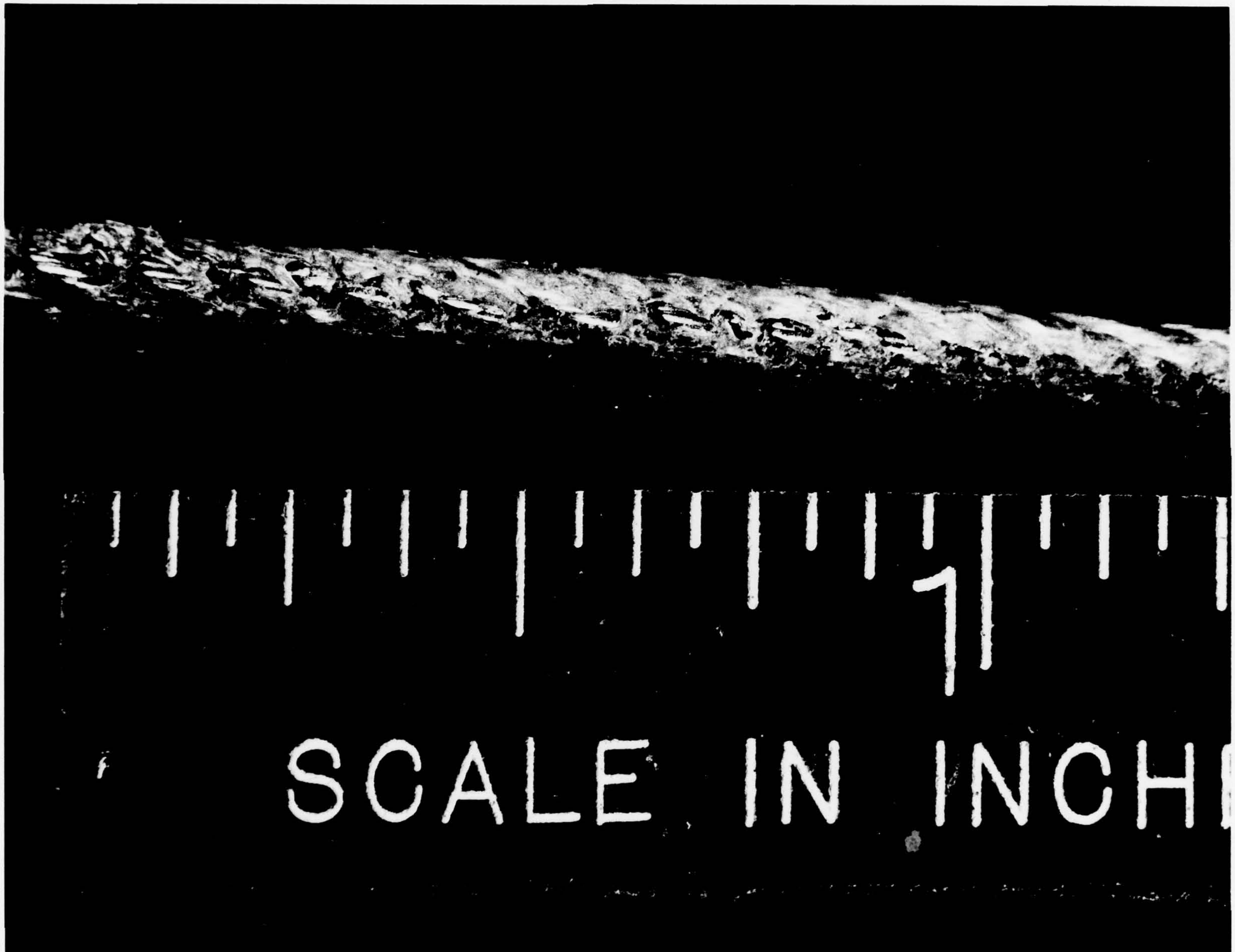


FIG 5

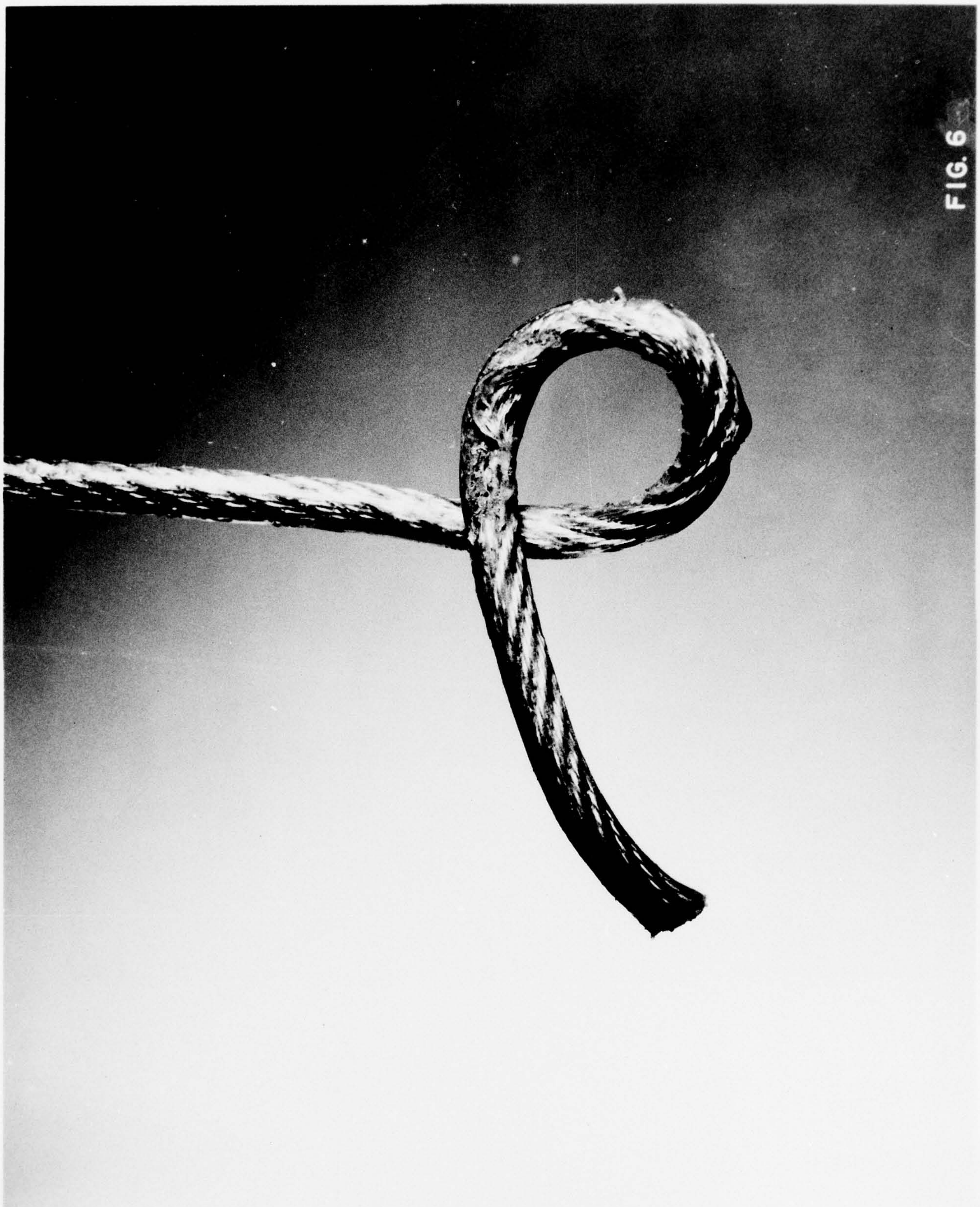
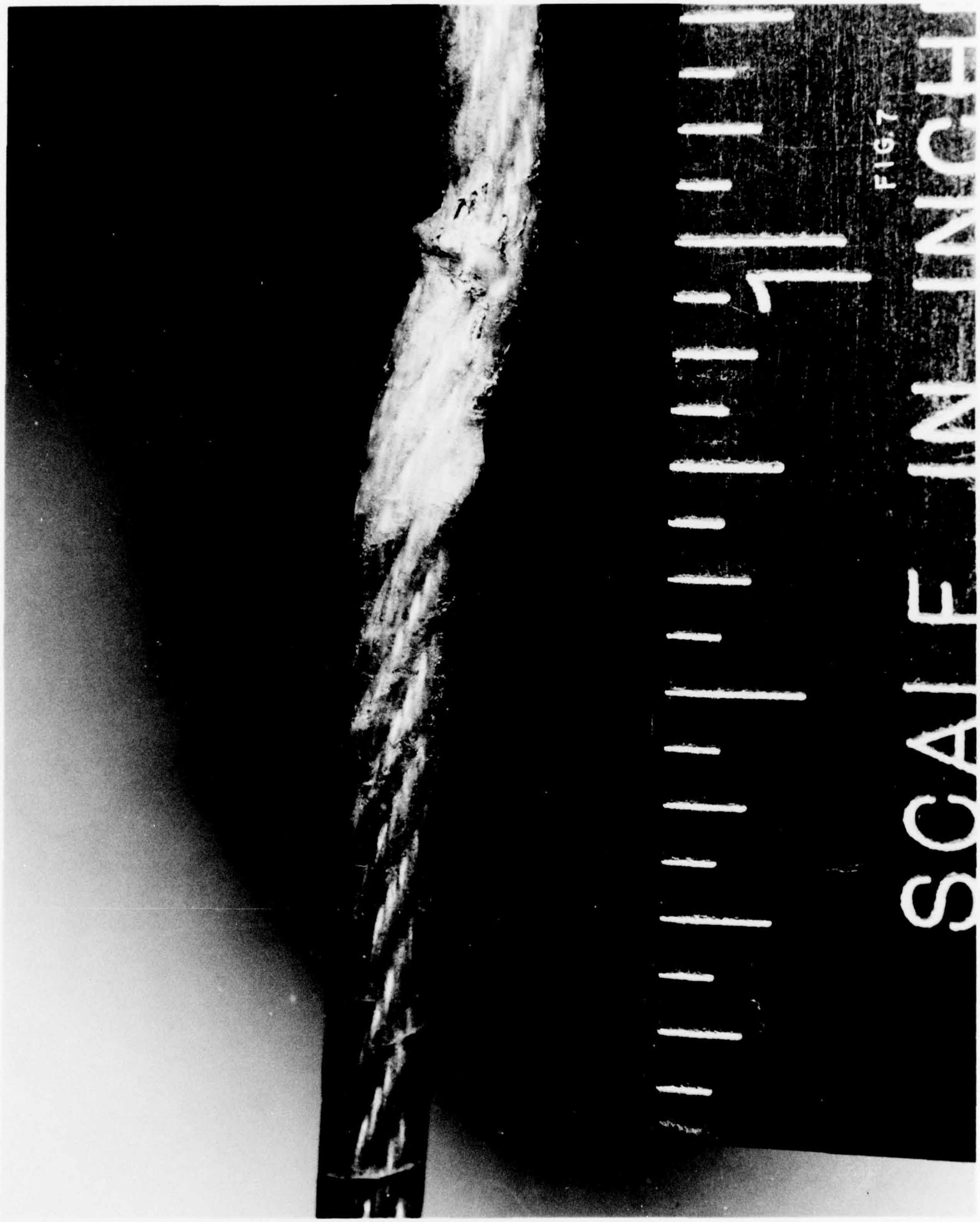


FIG. 6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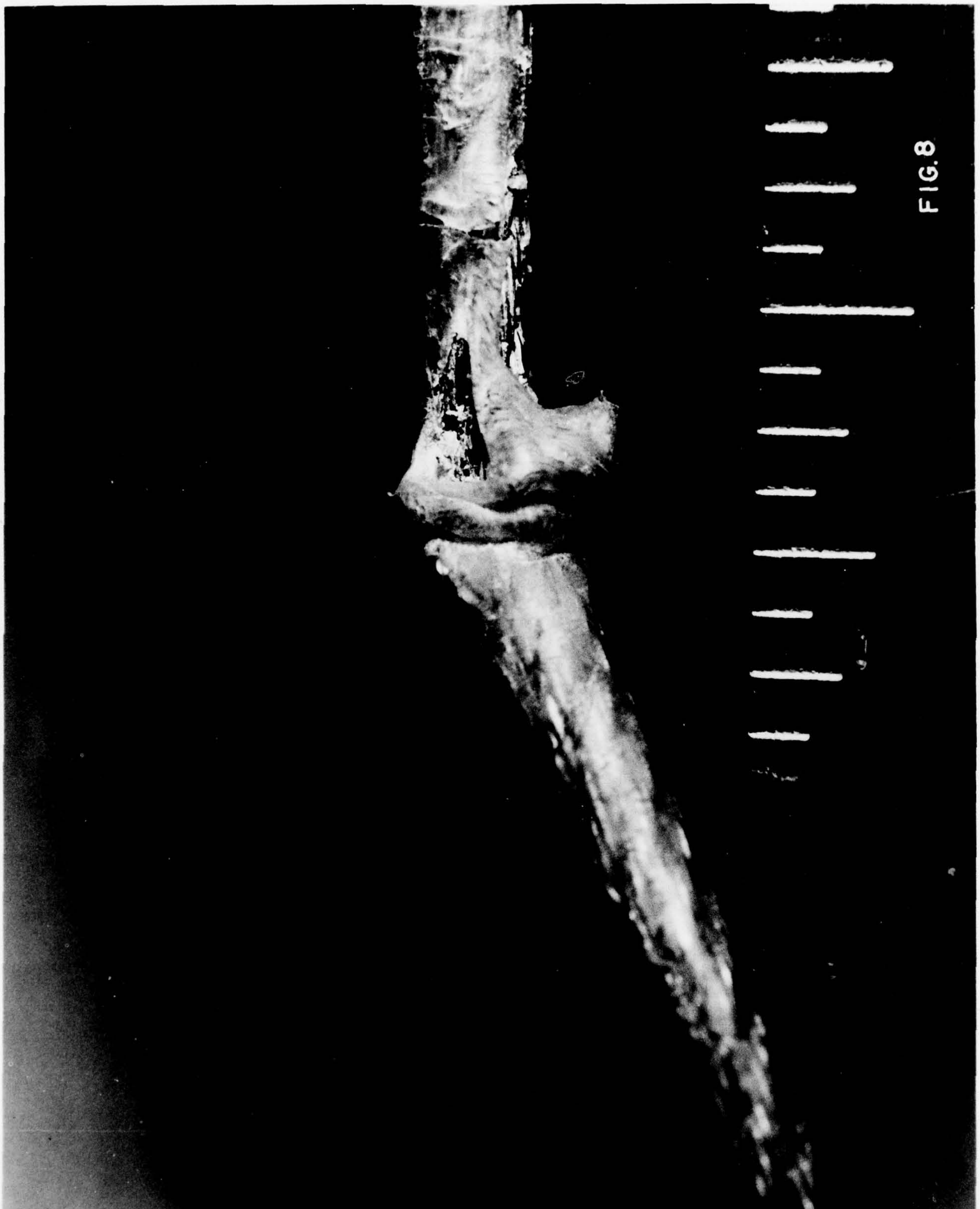

FIG. 8

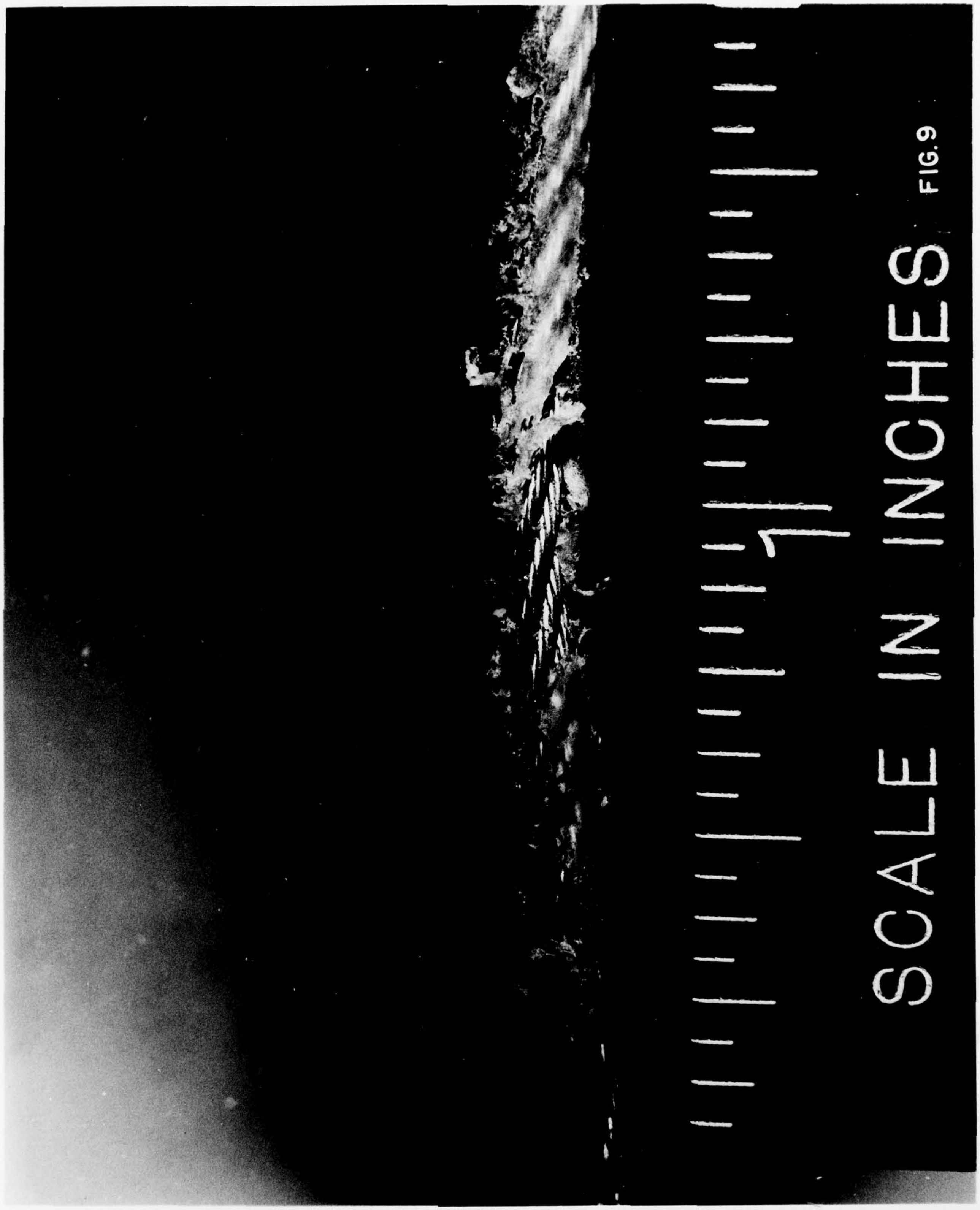

FIG.9

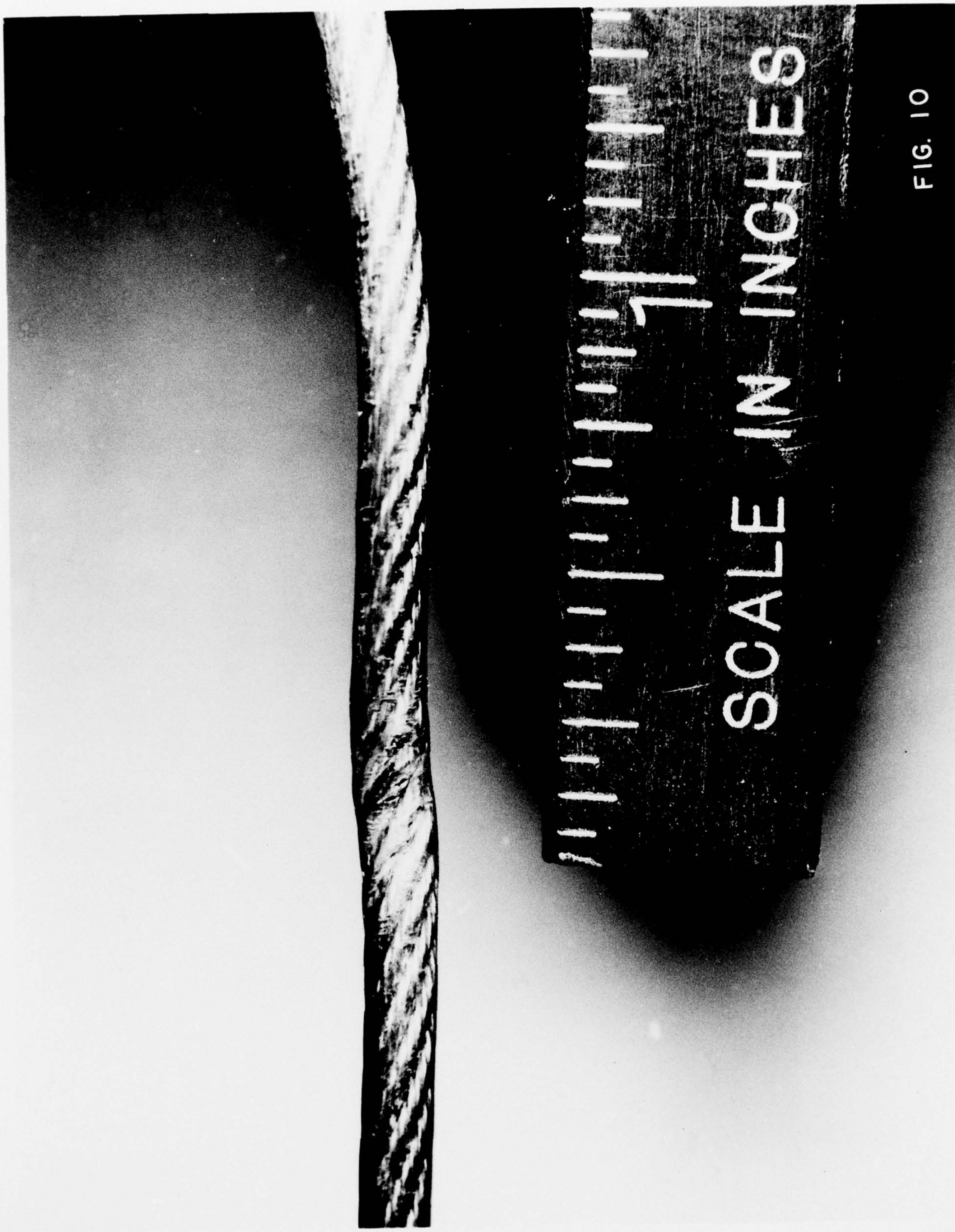

FIG. 10

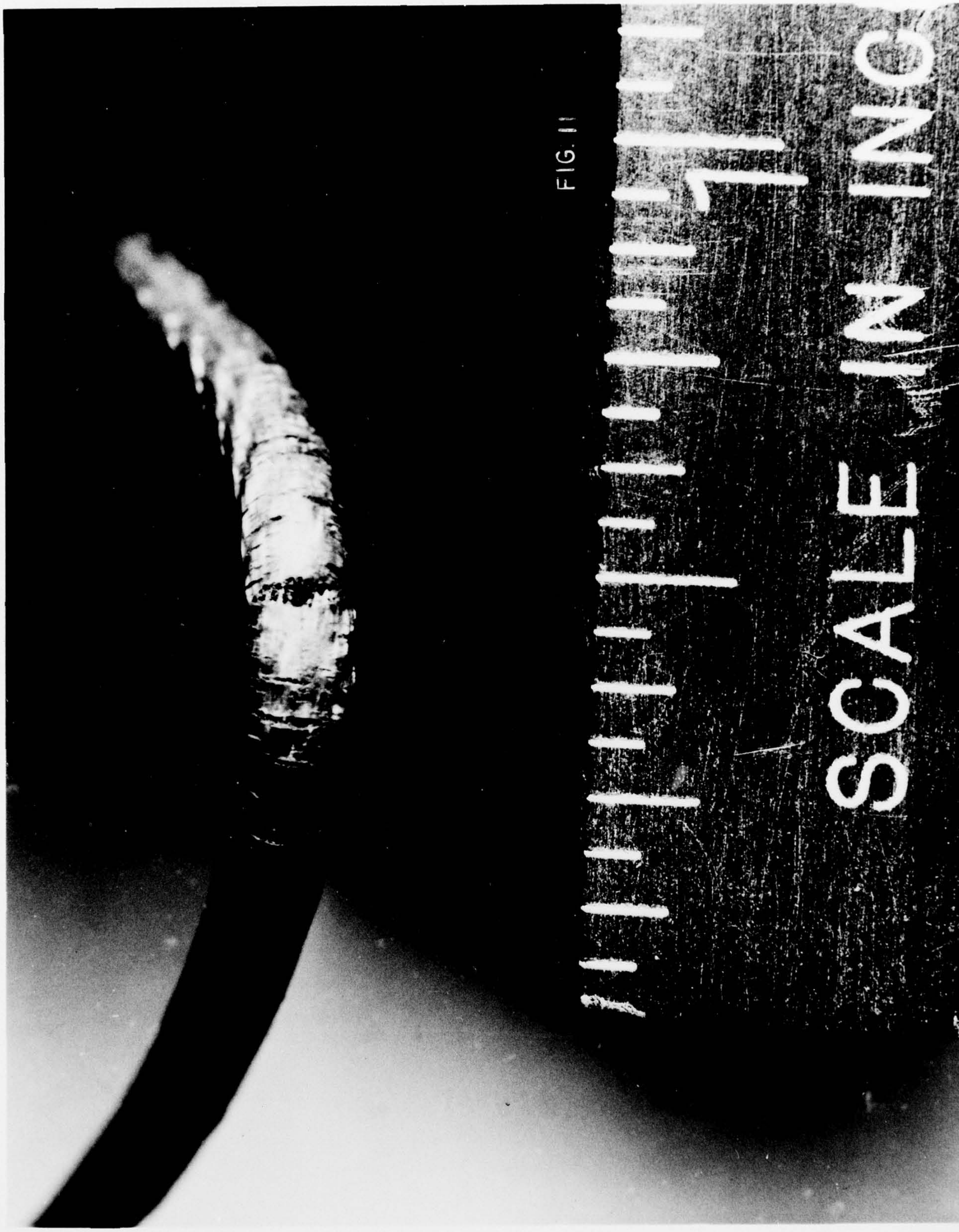

FIG. 11

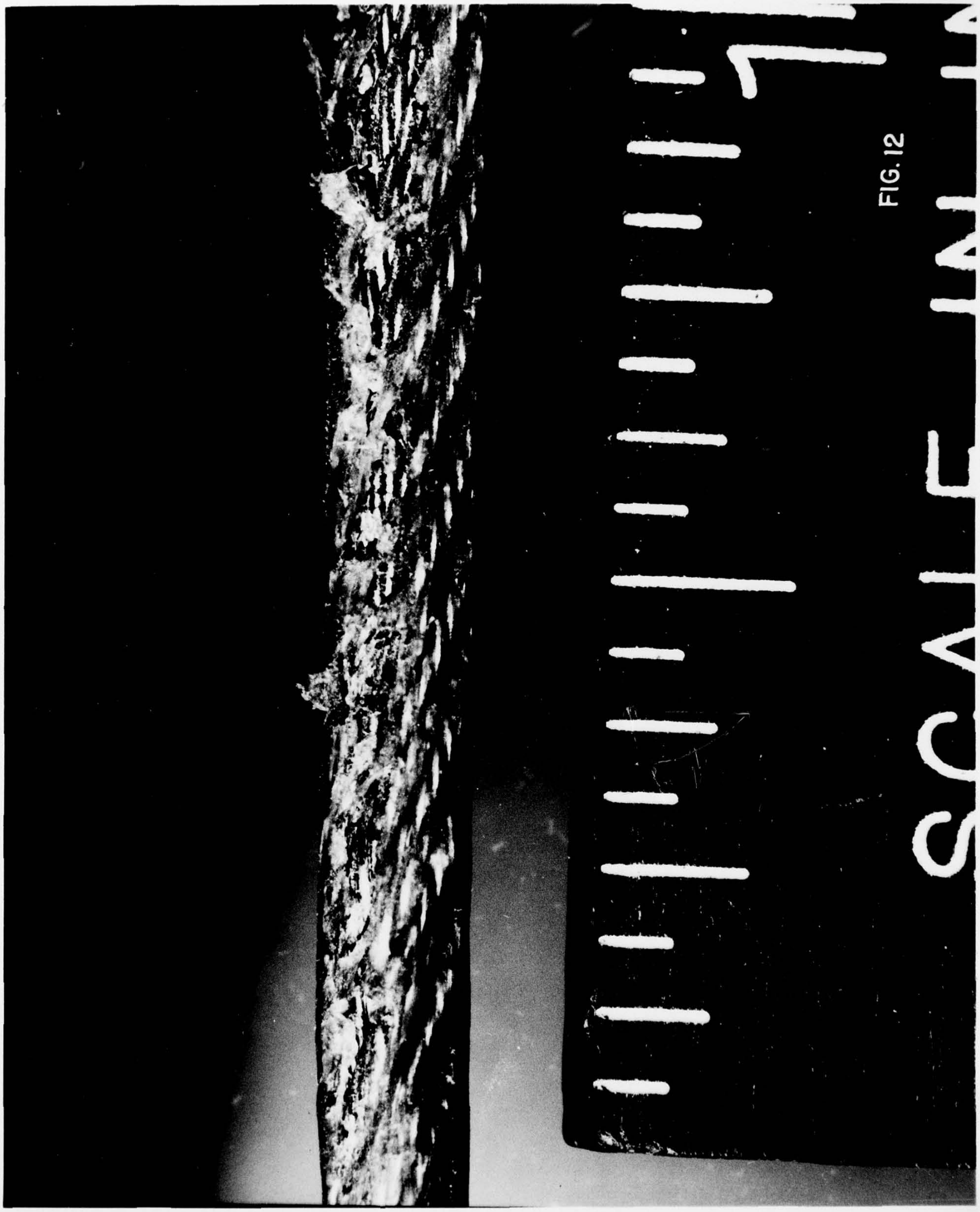

FIG. 12

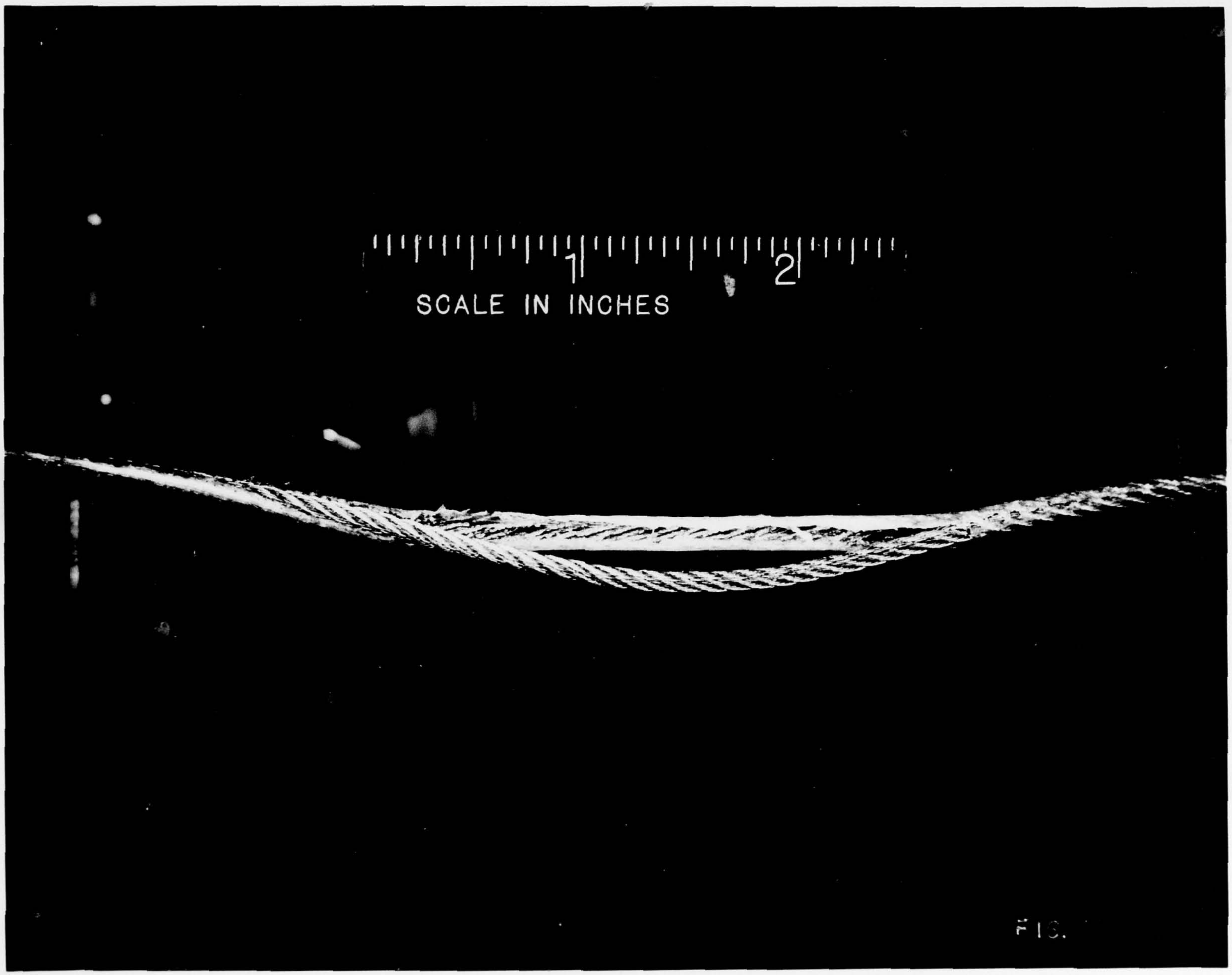
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FIG.

FIG. 14

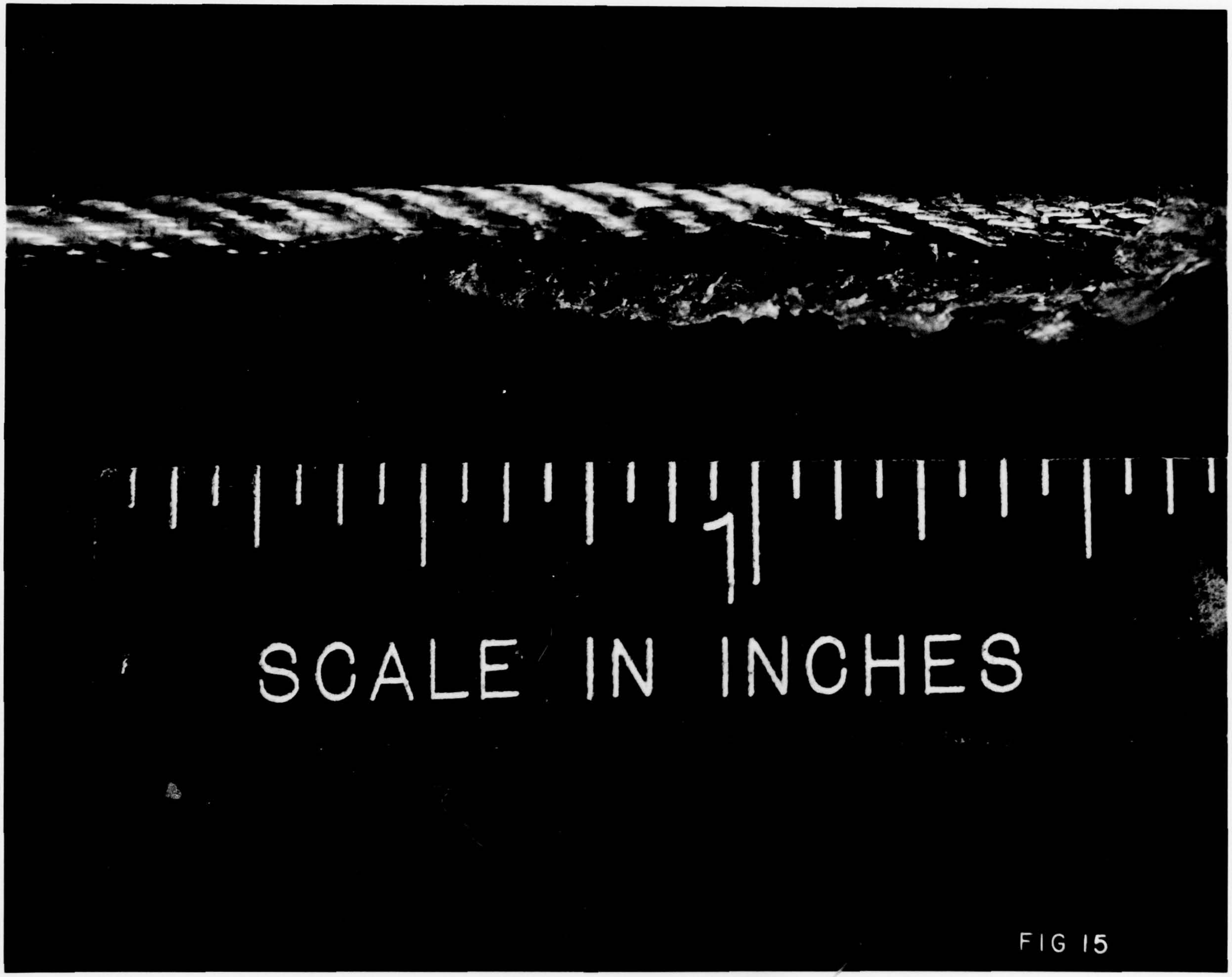

FIG 15

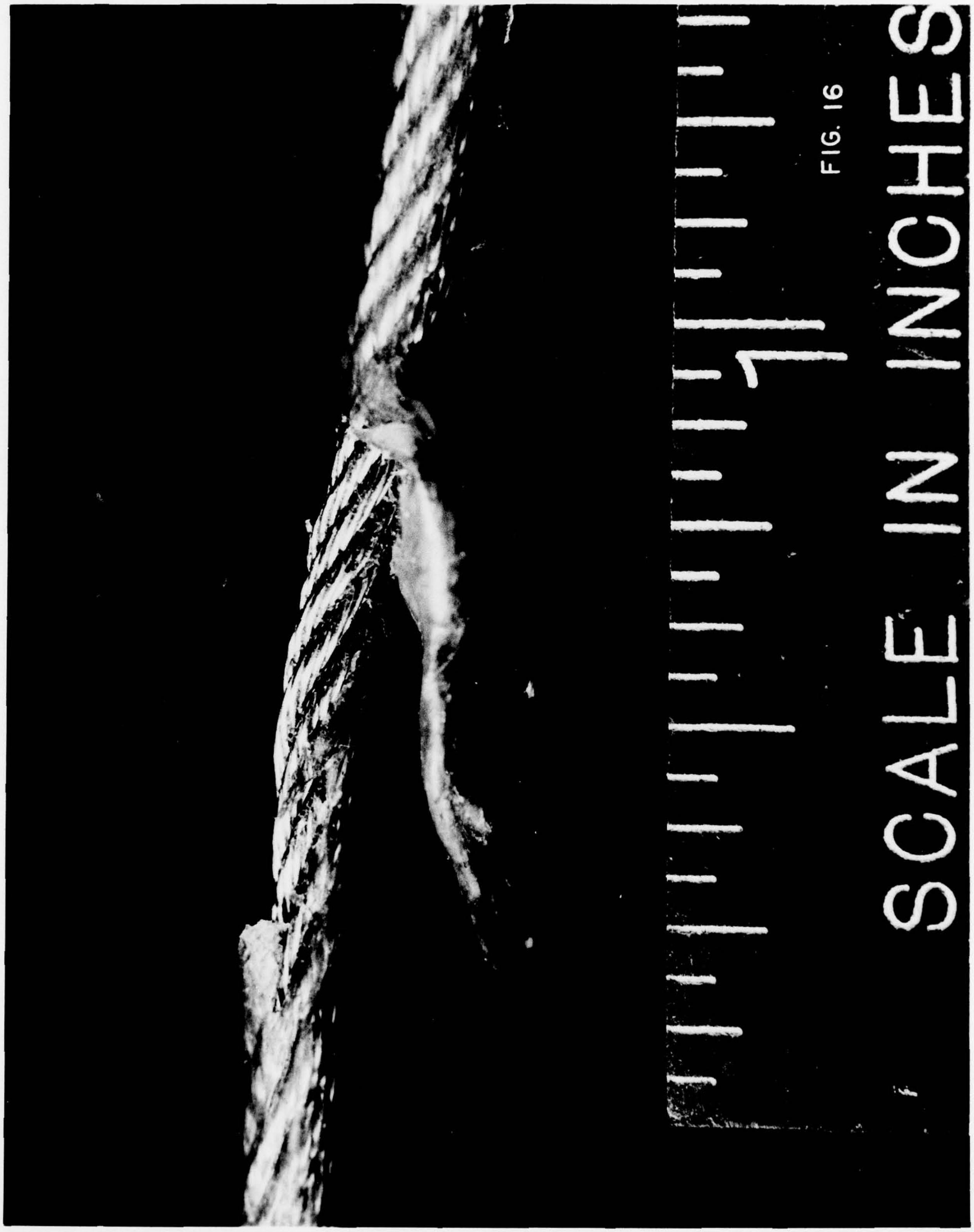
FIG. 16
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SCALE IN INCHES

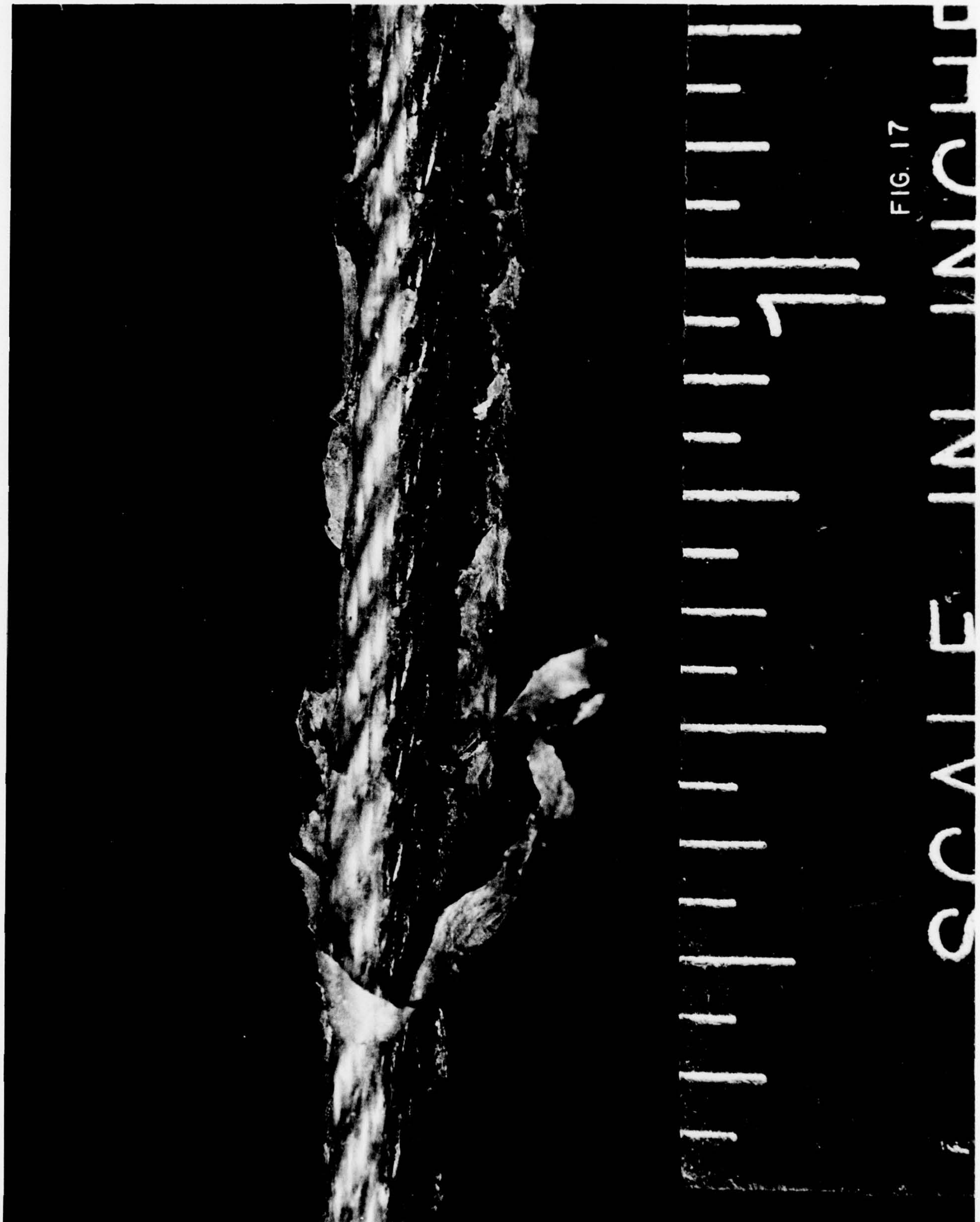
FIG. 17
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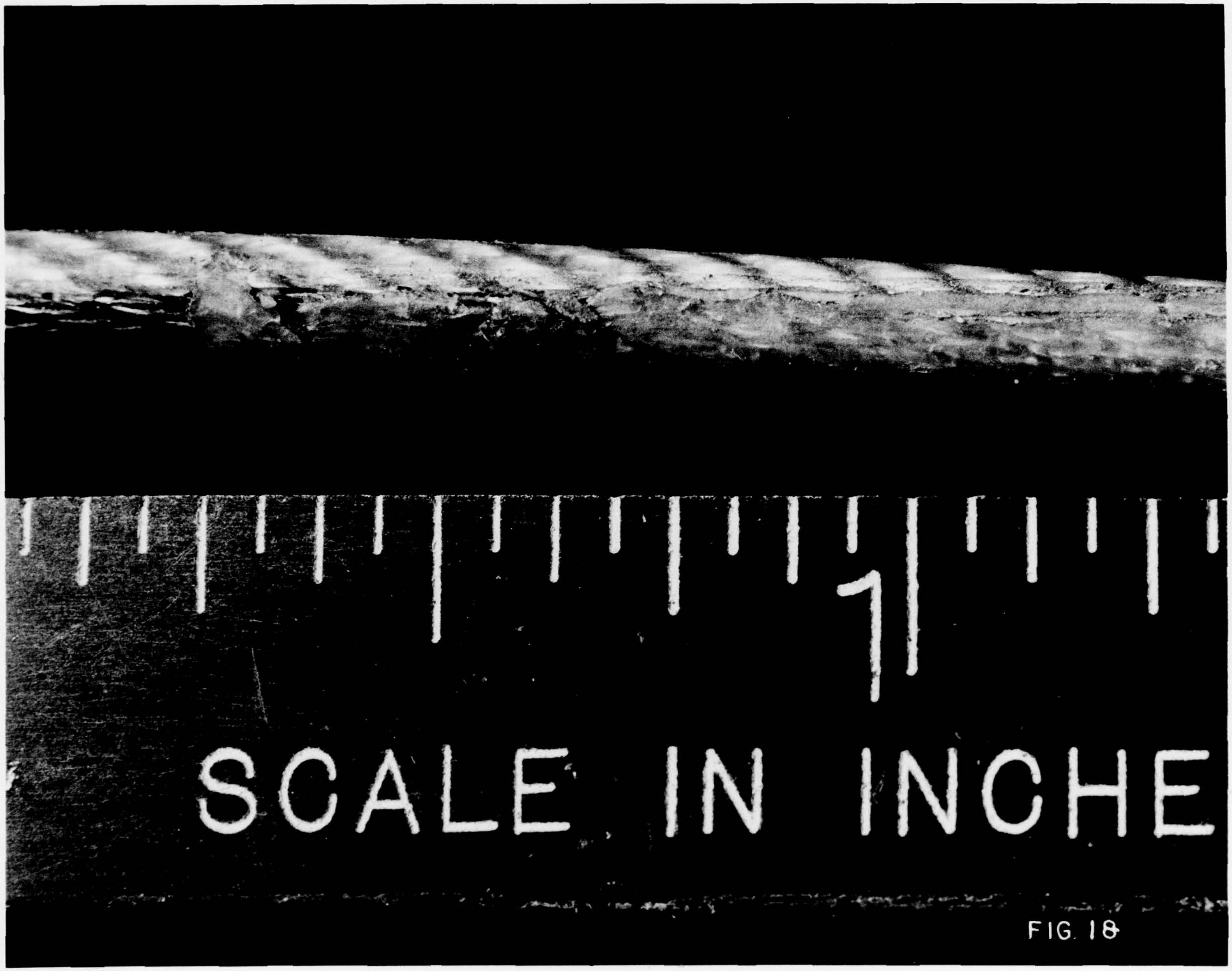
SCALE IN INC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SCALE IN INCHE
FIG. 18

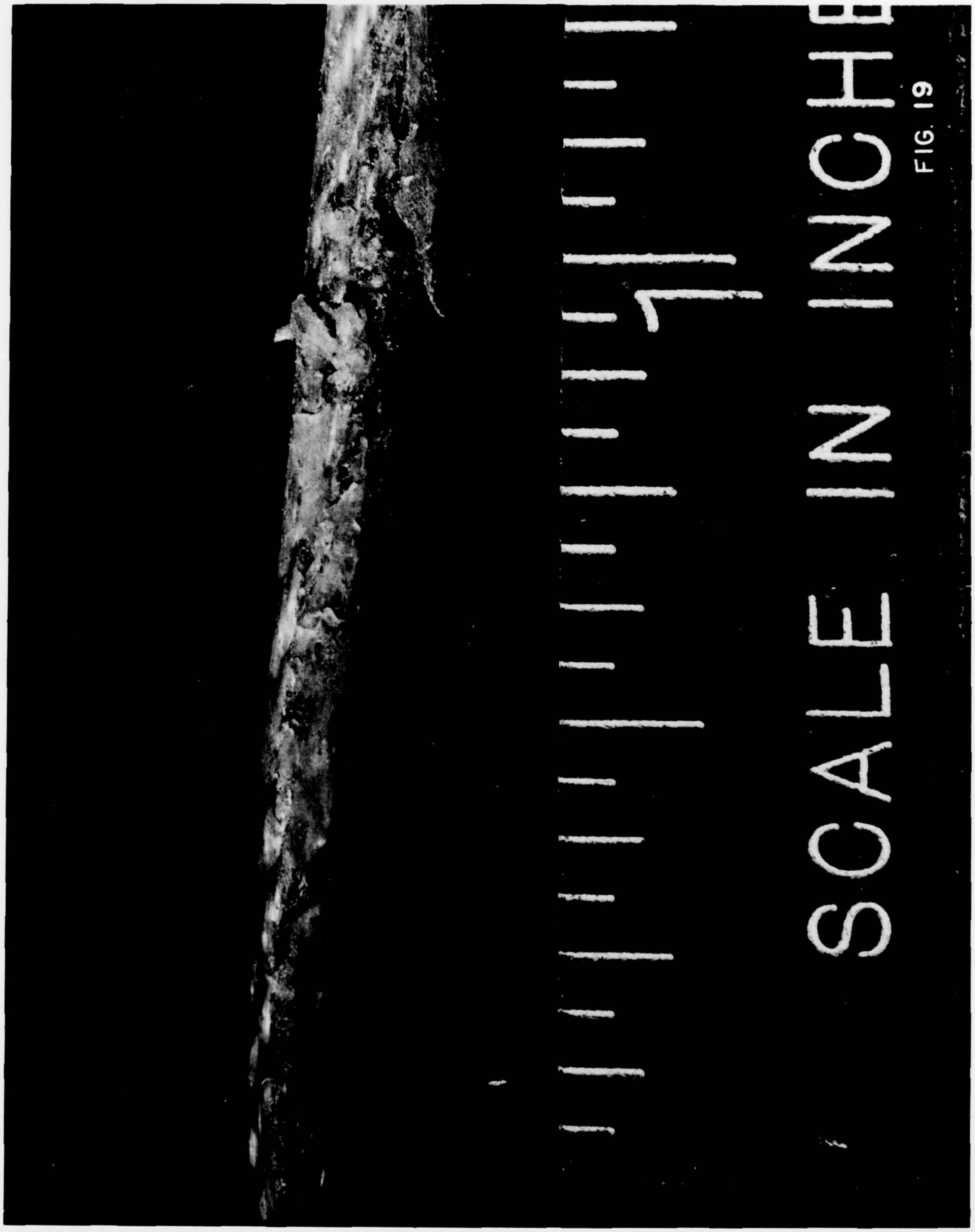

FIG. 19

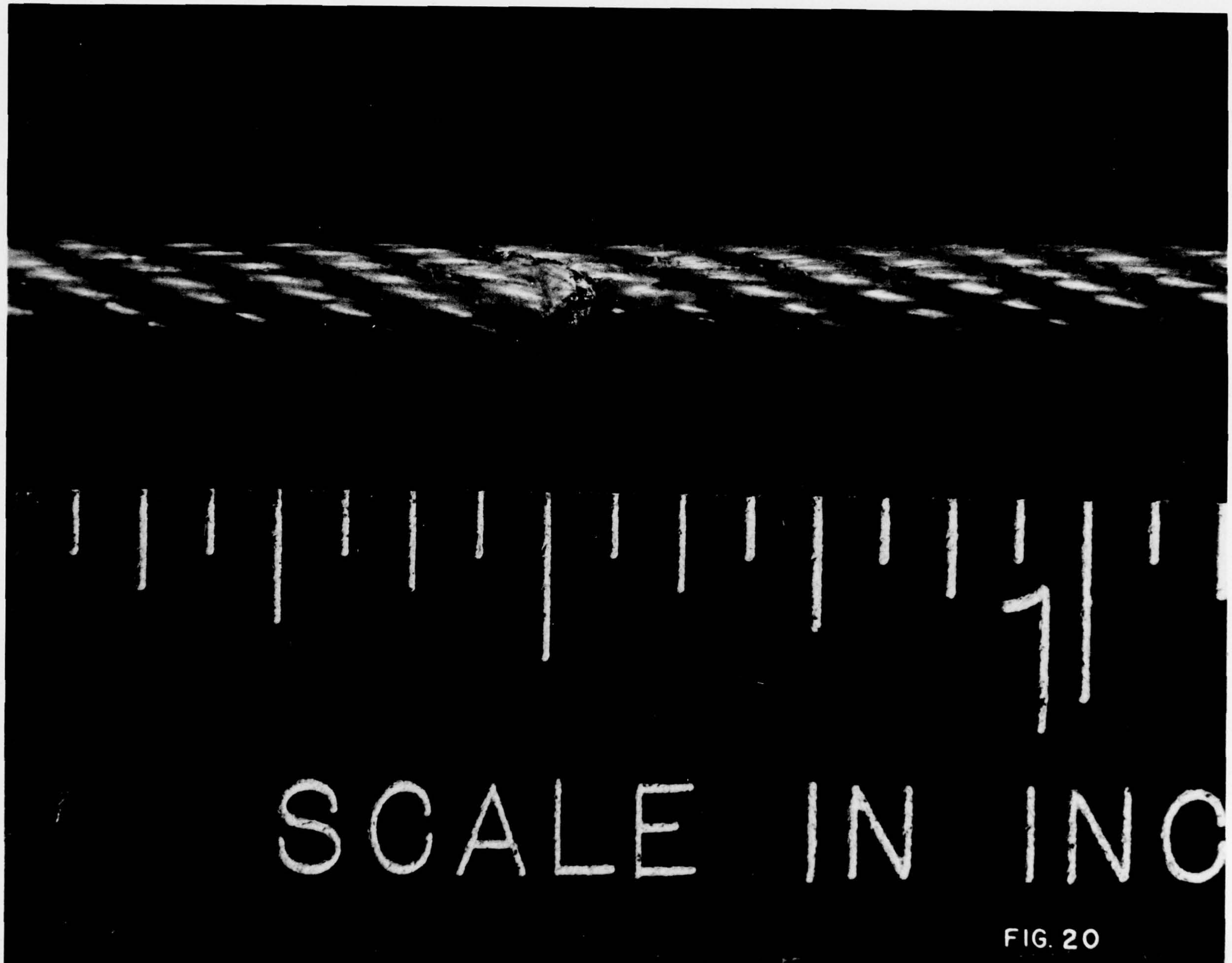

FIG. 20

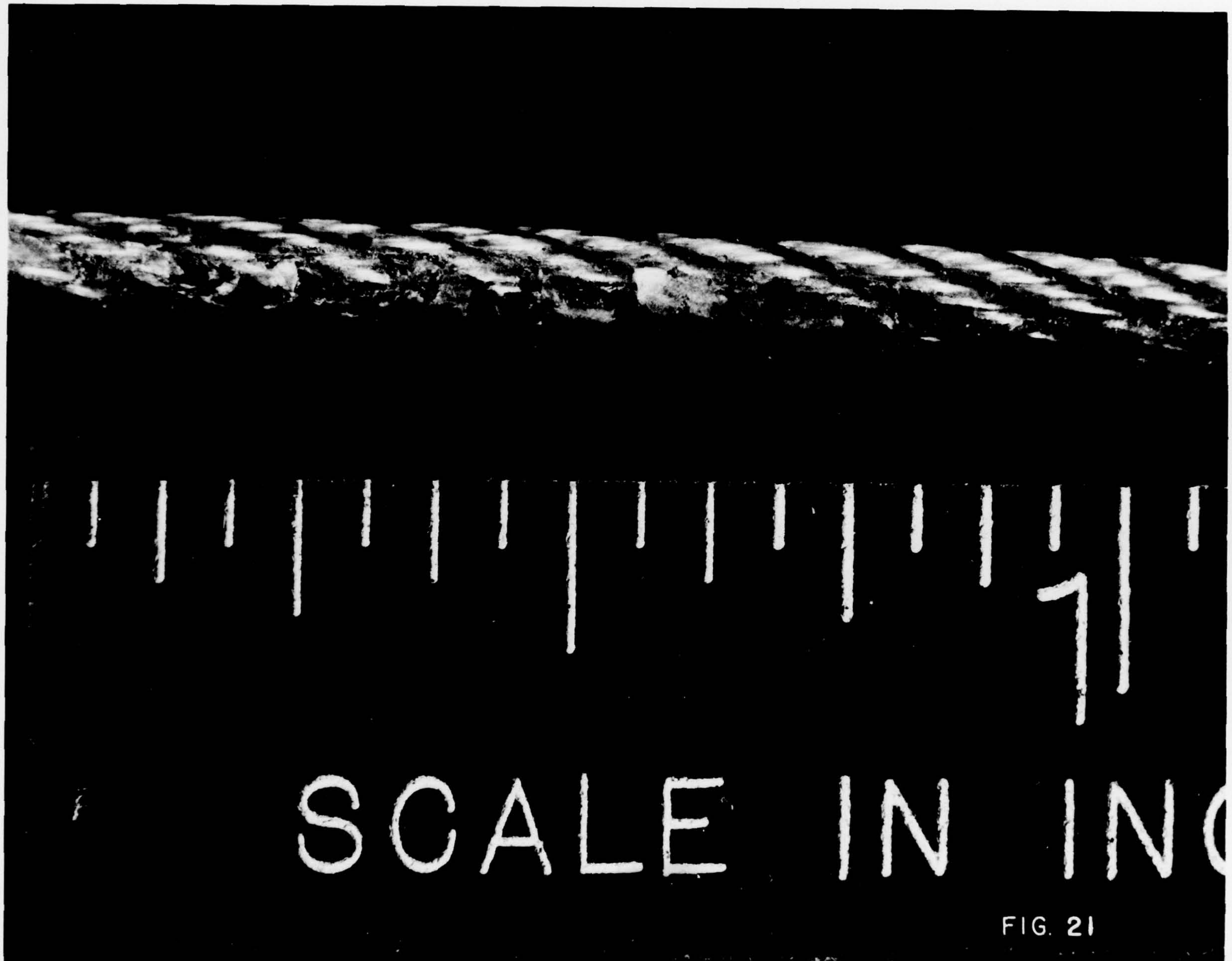

FIG. 21

FIG. 22